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APPENDIX A

REFERENCES

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APPENDIX B

GLOSSARY OF TERMS

AND ABBREVIATIONS

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AND ABBREVIATIONS

The explanation of terms used in the text is prepared according to the general usages developed during operations on the INEL site. Where possible, the explanations are developed also in accordance with established standards.

Acronyms, a word identified by first letters of a series of words, are also listed.

A

acre	a unit of area measurement equal to 43,560 ft^2
activation	the induction of radioactivity in material by irradiation with neutron radioactive material, a radiation generating machine, or a nuclear reactor
activity	a measure of the rate at which a material is emitting nuclear radiations, usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time; the standard unit of activity is the curie (Ci)
alpha radiation	an emission of particles (helium nuclei) from a material undergoing nuclear transformation; the particles have a nuclear mass number of four and charge of plus two
alpha waste	waste material which is contaminated by radionuclides which emit alpha particles, particularly transuranic elements
aquifer	a subsurface formation containing sufficient saturated permeable material to yield significant quantities of water
aseismic	not subject to earthquakes
atomic number	the number of protons in the nucleus of each chemical element
alluvial fan	rock deposit laid down by streams flowing from mountains into lowland regions

background radiation	the level of radioactivity in an area, which is produced by sources other than the one of specific interest; in the INEL region, the background radiation is produced by naturally occurring radioactive materials in the crust of the earth, cosmic radiations, and the fallout from nuclear weapons tests
beta radiation	essentially weightless charged particles (electrons and positrons) emitted from the nucleus of atoms undergoing nuclear transformation
bioconcentration (bioaccumulation)	the process whereby an organic system selectively removes an element from its environment and accumulates that element in a higher concentration
biological oxygen demand (BOD)	a measure of the organic pollution of water, determined by the extent to which bacteria and other contained organisms in a water sample will use dissolved oxygen in a given period of time; therefore, a measure of the residual oxygen in the water for use by other organisms such as fish
biosphere	living beings together with their environment
biota	the plant and animal life of a region
biotic	caused by living organisms
blowdown	cooling tower effluent water with a higher dissolved solids content than natural water
body burden	the amount of specified radioactive material or the summation of the amounts of various radioactive materials present in an animal or human body at the time of interest
burial ground	an area specifically designated for the subsurface disposal of solid waste or excess materials

C

calcination	solidification method for disposal of liquid wastes involving (a) atomizing and coating of liquid on small granular solids and (b) heating to drive off moisture
cask	a container designed for the transporting of radioactive materials, the design usually includes special shielding, handling, and sealing features to provide positive containment of the materials and to minimize exposure of personnel
chemical oxygen demand (COD)	a measure of the extent to which all chemicals contained in a water sample use dissolved oxygen in a given period of time; therefore, a measure of residual dissolved oxygen in the water available for use by organisms such as fish
coliform (count, number)	a measure of the bacterial content of water; a high coliform count indicates potential contamination of a water supply by human waste
concentration guide	the average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding appropriate radiation dose standards (see maximum permissible concentration)
contamination (contaminated material)	the deposition, solvation, or infiltration of radionuclides on or into an object, material, or area whereupon the area, material, or object is considered ''contaminated''; loose contamination is considered removable by conventional decontamination methods; fixed contamination is not removable by conventional decontamination methods
controlled area	any specific region of the INEL into which entry by personnel is regulated by physical barrier or procedure
counts per minute (cpm)	the number of events per unit time recorded by an instrument designed to detect radioactive particles; especially used to indicate the relative amount of radioactive contamination

critical	the condition in which a material is undergoing nuclear fission at a self-sustaining rate; the critical mass of a material is that amount which will self-sustain nuclear fission when placed in an optimum arrangement in its present form; the minimum critical mass is the amount of a fissile isotope that will self-sustain nuclear fission when placed in optimum conditions
criticality safety	those procedures and understandings necessary to the handling of fissile materials in a manner that will prevent them from reaching a critical condition
curie (Ci)	a unit of radioactivity defined as the amount of a radioactive material that has an activity of 3.7×10^{10} disintegrations per second (d/s); millicurie (mCi) = 10^{-3} curie; microcurie (μCi) = 10^{-6} curie; nanocurie (nCi) = 10^{-9} curie; picocurie (pCi) = 10^{-12} curie; femtocurie (fCi) = 10^{-15} curie

D

daughter products	the nuclides formed by the radioactive disintegration of a first nuclide (parent)
deactivated	the condition of a facility or disposal site where steps have been taken to preclude further operation or the further addition of waste materials
decay chain	the sequence of radioactive disintegrations in succession from one nuclide to another until a stable daughter is reached
decay heat	the thermal energy produced in a material by its own radioactive disintegrations
decontamination	the selective removal of radioactive material from a surface or from within another material
decommissioning	the process of removing a facility or area from operation and decontaminating and/or disposing of it or placing it in a condition of standby with appropriate controls and safeguards

disintegrations per minute (dpm)	the number of radioactive decay events occurring per unit time in a given amount of material
disposal	the planned release or placement of waste in a manner that precludes recovery or its placement in a manner which is considered permanent so that recovery is not provided
dose	a general term indicating the amount of energy absorbed from incident radiation by a specified mass
dose commitment	the integrated dose which results from an intake of radioactive material when the dose is evaluated from the beginning of intake to a later time (usually 50 years); also used for the long-term integrated dose to which people are considered committed because radioactive material has been released to the environment
drum	a metal or composition cylindrical container used for the transportation, storage, and disposal of waste materials

E

ecology	that branch of biological science which deals with the relationships between organisms and their environment
ecosystem	an assemblage of biota (community) and habitat
environmental surveillance	a program to monitor the impact on the surrounding region of the discharges from industrial operations
evapotranspiration	the combined loss of water from soil by evaporation from the soil and from the surfaces of plant structures
excursion	a sudden rapid increase of power produced when a reactor or other system of fissile material undergoes a sudden increase in reactivity
exposure	the condition of being made subject to the action of radiation
extraction	a chemical process for selectively removing materials from solutions

F

fallout	those radioactive materials deposited on the earth's surface and in the atmosphere following the detonation of nuclear weapons
fast flux (fast neutron)	a stream of neutrons having energies (velocities) near that imparted to them by a fission event; when applied to nuclear reactors, refers to those using high velocity neutrons to cause successive fission events
fissile	material capable of undergoing fission by any process
fissionable	material capable of undergoing fission by slow neutrons
fission (nuclear)	the division of a nucleus into two nuclides of lower mass, usually accompanied by the expulsion of gamma rays and neutrons
fission products	the nuclides formed by the division of a heavier nucleus; most usually in a nuclear reactor
foodchain	a linear sequence of successive utilizations of nutrient energy by a series of species
foodweb	the concept of nutrient energy transfer (including decomposition) between species in an ecosystem
fuel (nuclear, reactor)	fissionable material used as the source of power when placed in a critical arrangement in a nuclear reactor
fuel separation (fuel reprocessing)	processing of irradiated (spent) nuclear reactor fuel to recover useful materials as separate products, usually separation into plutonium, uranium, and fission products

G

gamma radiation	electromagnetic energy emitted in the process of a nuclear transition
gamma scan	process of measuring the energy spectrum of the gamma rays emitted by a material in order to determine its constituent nuclides

gastrointestinal dose (GI)	the dose to the stomach and lower tract of humans and animals via external exposure or via internal transport of radioactive material
GeigerMuller Tube	a gas-filled tube used to detect radiation events by the ionization pulse produced in the gas; used on a GM counter
groundwater	water which exists or flows below the surface (within the zone of saturation)

H

habitat	the abiotic characteristics of the place biota live
half-life	the time required for the activity of a radionuclide to decay to half its value; used as a measure of the persistence of radioactive materials, each radionuclide has a characteristic constant half-life
high efficiency particulate air filter (HEPA)	an air filter capable of removing at least 99.97% of the particulate material in an air stream
high-heat waste	liquid radioactive waste which generates sufficient fission product decay heat to cause self-boiling and self-concentration
high-level liquid waste	the aqueous wastes resulting from the operation of the first-cycle extraction system, or equivalent concentrated wastes from subsequent extraction cycles; or equivalent wastes from a process not using solvent extraction, in a facility for processing irradiated reactor fuels
hood	a canopy and exhaust duct used to confine hazardous materials in order to reduce the exposure of industrial workers
hypothetical maximum individual (max man)	a postulated person who is assumed to receive the maximum credible radiological dose through each of the exposure pathways from the source being considered

I

inactive	the condition of a facility or disposal site which is not presently being operated or to which materials are not being added
inversion	a condition where temperature increases with height in the atmosphere
ion exchange	process for selectively removing a constituent from a waste stream by reversibly transferring ions between an insoluble solid and the waste stream; the exchange medium (usually a column of resin or soil) can then be washed to collect the waste or taken directly to disposal; for example, a hot water softener
irradiation	exposure to radiation by being placed near a radioactive source; usually in the case of fuel materials, being placed in an operating nuclear reactor
isopleth	a line connecting all points of equal air concentration in plotting that air concentration at ground level as a function of direction and distance from a point of release
isotope	nuclides with the same atomic number, (i.e., the same chemical element) but with different atomic masses; although chemical properties are the same, radioactive and nuclear properties may be quite different for each isotope of an element

L

leaching pond	an excavation used for the disposal of liquids so that the soil will remove contaminants while allowing water and other solvents to pass through
lithologic	pertaining to the characteristics and study of rocks
long-lived isotope	a radioactive nuclide which decays at such a slow rate that a quantity of it will exist for an extended period; usually radionuclides whose half-life is greater than 3 years

low-level liquid waste	liquid wastes that can be discharged to the environment with assurance that persons will not be exposed to concentrations in excess of those prescribed in ERDAM-0524
	M
man-rem	used as a unit of population dose; the average dose per individual expressed in rems times the population affected
maximum permissible concentration (MPC)	the average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding an established standard of radiation dose limitation
	N
neutron	a particle existing in or emitted from the atomic nucleus; it is electrically neutral and has a mass approximately equal to that of a stable hydrogen atom
neutron activation	the process of irradiating a material with neutrons so that the material itself is transformed into a radioactive nuclide
nitrogen oxides (NO_x)	a mixture of nitrogen-oxygen containing compounds formed as gaseous waste effluents during the combustion of most fossil fuels
nuclear fission	see fission
nuclear radiation	particles and electromagnetic energy given off by transformations occurring in the nucleus of an atom
nuclear reactor	a device constructed of fissionable material such that a chain of fission events can be maintained and controlled to meet a particular purpose
nuclide	a species of atom having a specific mass, atomic number, and nuclear energy state
nucleus	the positively charged center of an atom
	P
penetrating radiation	forms of radiant energy which are capable of passing through significant thicknesses of solid material; these usually include gamma rays, X rays and neutrons

permissible dose	that dose of ionizing radiation which, in the light of present knowledge, carries negligible probability of causing severe somatic injury or genetic effect
pH	a measure of the relative acidity or alkalinity of solution; a neutral solution has a pH of 7, acids have pH's of 7 to 1, bases have pH's of 7 to 14
phytoplankton	microscopic plants that live drifting in a body of water
population dose (population exposure)	the summation of individual radiation doses received by all those exposed to the source or event being considered

R

rad	a special unit of measure for the absorbed dose of radiation; one rad equals 100 ergs absorbed per gram of material
radiation (ionizing)	particles and electromagnetic energy emitted by nuclear transformations which are capable of producing ions when interacting with matter; gamma rays and alpha and beta particles are primary examples in INEL waste
radiation survey	evaluation of an area or object with instruments in order to detect, identify, and quantify radioactive materials and radiation fields present
radioactive (decay)	property of undergoing spontaneous nuclear transformation in which nuclear particles or electromagnetic energy are emitted
radioiodines	isotopes of iodine which are radioactive
radionuclide	a nuclide which is radioactive
radiotoxicity	the property of a material of being able to adversely affect biological organisms through the mechanism of nuclear radiation
radwaste	waste materials which are radioactive
raptor	bird of prey
reactivity	a measure of the capability of a system to maintain criticality; systems with high reactivity are capable of undergoing rapid excursions

	of increasing power; systems with low reactivity will undergo slower excursions; systems with negative reactivity will not become critical
reactor	a nuclear reactor
regolith	rock ''waste'' or surface mantle of unconsolidated rock debris
release limit (release guide)	a control number which regulates the concentration or amount of radioactive material released to the environment in an industrial situation; usually dose to persons in the environment derived from environmental behavior of the released material so that the dose is kept below a selected control value
rem	a unit of measure for the dose of ionizing radiation which gives the same biological effect as one roentgen of X rays; one rem approximately equals one rad for X, gamma, or beta radiation
reprocessing	chemical processing of irradiated nuclear reactor fuels to remove desired constituents
retention basin	an excavated and lined area used to hold contaminated fluids until radioactive decay reduces activities to levels permissible for release
retired facility	a facility which has been shut down with no intentions of restarting and which has had appropriate controls and safeguards placed on it
roentgen	a unit of measure of ionizing electromagnetic radiation (X and gamma); one roentgen corresponds to the release by ionization of 83.8 ergs of energy per gram of air
rupture	a breach of the metal cladding of a production reactor fuel element thereby releasing radioactive materials to reactor cooling streams
	S
sanitary landfill	a burial operation for the purpose of disposing of sanitary wastes

sanitary sewage	human wastes and other nonradioactive material for disposal to preserve public health
scintillation (counter)	light flashes produced in crystalline material by ionizing radiation; measurement of the level of activity of the source
seepage pond	an artificial body of surface water formed by discharge from INEL process operations
seismicity	the tendency for the occurrence of earthquakes
shielding	bulkheads, walls, or other constructions used to absorb radiation in order to protect personnel or equipment
short-lived isotope	a radioactive nuclide which decays so rapidly that a given quantity is transformed into its daughter products within a short period (usually those with a half-life of days or less)
smear	a means of measuring loose surface contamination on an object by wiping it with paper, gauze, etc., and then measuring the disintegrations per minute on the wipe with an instrument
solid wastes (radioactive)	either solid radioactive material or solid objects which contain radioactive material or bear radioactive surface contamination
sorptive capacity	the measure of a material's ability to sorb specific constituents from liquid as it passes through the material
stability (atmospheric)	a description of the atmospheric forces on a parcel of air following vertical displacement in an atmosphere otherwise in hydrostatic equilibrium; if the forces tend to return the parcel to its original level, the atmosphere is stable; if the forces tend to move the parcel further in the direction of displacement, the atmosphere is unstable; if the air parcel tends to remain at its new level, the atmosphere has neutral stability
storage	retention of radioactive waste in some type of man-made device, such as a tank or vault, in a manner permitting retrieval
sulfur oxides (SO_2/SO_3)	compounds formed as waste effluents during the burning of some fossil fuels

T

tank	a large metal container located underground for storage of liquid wastes
tank farm	an installation of interconnected underground containers (tanks) for storage of high-level waste
tectonic	pertaining to, or designating the rock structures resulting from deformation of the earth's crust
tracer	a radionuclide(s) or chemical introduced in minute quantities to a system or process for the purpose of using radiation or chemical detection techniques to follow the behavior of the process or system
transmutation	the process whereby one nuclide changes (or is changed) into another; usually by the addition of nuclear particles
transuranium	nuclides having an atomic number greater than that of uranium (i.e., greater than 92)
transmissivity	a coefficient relating the volumetric flow through a unit width of groundwater to the driving force (hydraulic potential); a function of both the porous medium, fluid properties, and saturated thickness of the aquifer

V

vadose zone	the unsaturated region of soil between the ground surface and the water table

W

water table	upper boundary of an unconfined aquifer surface below which saturated groundwater occurs; defined by the levels at which water stands in wells that barely penetrate the aquifer
wind rose	a diagram designed to show the distribution of prevailing wind directions at a given location; some variations include wind speed groupings by direction

List of Abbreviations

ACC	Allied Chemical Corporation
AEC	Atomic Energy Commission
ANC	Aerojet Nuclear Company
ANL-W	Argonne National Laboratory-West
ANPP	Aircraft Nuclear Propulsion Program
A1W	Prototype Nuclear Surface Ship Propulsion System
APS	Atmospheric Protection System
ARA	Auxiliary Reactor Area
ARMF	Advanced Reactivity Measurement Facility
ATR	Advanced Test Reactor
ATRC	Advanced Test Reactor Critical Facility
BORAX	Boiling Water Reactor Experiment
cc	Cubic Centimetre
cm	Centimetre
CERT	Controlled Experimental Radioiodine Test
CFA	Central Facilities Area
CFR	Code of Federal Regulations
Ci	Curie
EBOR	Experimental Beryllium Oxide Reactor
EBR-I and -II	Experimental Breeder Reactors I and II
ECF	Expended Core Facility
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ETR	Engineering Test Reactor
EFS	Experimental Field Station
EOCR	Experimental Organic Cooled Reactor

ETRC	Engineering Test Reactor Critical Facility
FAA	Federal Aviation Agency
g	gram (seismology, g. = gravity)
GCRE	Gas Cooled Reactor Experiment
HEPA	High Efficiency Particulate Air
HFEF	Hot Fuel Examination Facility
HSL	Health Services Laboratory
IET	Initial Engine Test
ICPP	Idaho Chemical Processing Plant
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss-of-Coolant Accident
LPT	Low Power Test
LOFT	Loss-of-Fluid Test
µCi	Microcurie
mCi	Millicurie
mrad	Millirad
mREM	Millirem
mR/hr	Milli-Roentgen per hour
NOAA	National Oceanic and Atomospheric Administration
NRF	Naval Reactor Facilities
NRTS	National Reactor Testing Station
OMRE	Organic Moderated Reactor Experiment
PBF	Power Burst Facility
PEW	Process Equipment Waste
RaLa	Radioactive Lanthanum
RWMC	Radioactive Waste Management Complex
S5G	Prototype Nuclear Submarine Propulsion System

SDA	Subsurface Disposal Area
S1W	Prototype Nuclear Submarine Propulsion System
SL-1	Stationary Low Power Test Reactor
SNAP	Systems for Nuclear Auxiliary Power
SPERT	Special Power Excursion Reactor Test
TAN	Test Area North
TDA	Transuranic Disposal Area
TSA	Transuranic Storage Area
TRA	Test Reactor Area
TREAT	Transient Reactor Test Facility
TSF	Technical Support Facility
WEC	Westinghouse Electric Corporation
WCF	Waste Calciner Facility
WMIS	Waste Management Information System
ZPPR	Zero Power Plutonium Reactor

APPENDIX C

LISTING AND DISPOSITION OF PAST INEL RELEASES

APPENDIX C

LISTING AND DISPOSITION OF PAST

INEL RELEASES

In addition to the major programmatic and accidental releases discussed in Section II.C, several other events of lesser importance have occurred at INEL. Brief discussions of those which were of significant environmental concern are presented chronologically in this appendix.

Many of the releases were related to programs no longer being conducted and/or presently decommissioned facilities. Others have resulted in upgrading of equipment, procedures, training, etc., to minimize the possibility of similar occurrences. Where the data were available, quantitative release values are given. In all the cases listed, no real or potential long-term commitment of resources or significant cumulative environmental impact exists.

1. BORAX-I Destruction

After a series of transient tests, the BORAX-I reactor was intentionally subjected to a rapid power excursion in July 1954. The excursion produced 135 MW of energy and resulted in melting most of the fuel plates and gross damage to the reactor. A description of the reactor is given in Section II.A.12.

Monitoring teams that were dispatched shortly after the excursion determined the trajectory of the released effluent to have been roughly in a southwesterly direction toward the INEL Radioactive Waste Management Complex. Surveys of the total fission product radioactivity of all the debris indicated that practically all of the fuel originally in the reactor could be accounted for within a radius of 350 ft around the original reactor location, with the majority in an area 350 x 200 ft just south of the reactor. Approximately 5,000 ft^2 of ground was covered with a 6-in. layer of gravel to reduce the dose rates to acceptable levels. During the past 20 years, the radiation levels in the area have decayed to near background levels.

2. ICPP Well Discharge

In July 1954 during a routine transfer to the discharge well, permissible levels were exceeded, and 51 μCi of long-lived fission product activity were released in 244,000 gallons of liquid.

3. EBR-I Fuel Meltdown

In November 1955 the EBR-I experienced an excursion which resulted in melting of some of the fuel elements. The reactor building was slightly contaminated from released fission product gases, but there were no significant personnel exposures or environmental releases.

4. Release to ICPP Discharge Well

In August 1956 approximately 1 Ci of long-lived fission product activity was released to the ICPP discharge well.

5. RaLa Release

In February 1958 activity from a RaLa process run was accidentally released into the building for approximately 5 min with minor exposures to personnel. An estimated 1 μCi of fission product activity, including iodine-131, was released to the environment.

6. BORAX-IV Fuel Defect Test

In March 1958 the BORAX-IV reactor was intentionally operated at a power of 2.4 MW with a large number of defective fuel elements. During the tests, radioactive fission products leaked from the fuel causing high radiation and building contamination. Environmental releases were primarily limited to cleanup operations.

7. Iodine Release at ICPP

In March 1958 approximately 1 Ci of iodine-131 was released to atmosphere during a routine waste transfer operation at ICPP.

8. Blower Failure at ICPP

In August 1958 an atmospheric release of approximately 10 μCi of long-lived fission product activity occurred at the ICPP owing to a blower failure.

9. Solvent Burner Release

In September 1958 approximately 0.25 Ci of long-lived particulate activity was released from the ICPP solvent burner via the main stack.

10. Fuel Element Cutting Facility Release

In October 1958 a filter failure resulted in a 1,200-Ci particulate release to atmpshere consisting primarily of long-lived fission products, from the fuel element cutting facility at ICPP which contaminated the land immediately adjacent to the facility.

11. Liquid Spill at ICPP

An accidental liquid spill in the fuel process building at ICPP required extensive decontamination activities from November 1958 through April 1959. As a result, a considerable quantity of liquid waste and decontamination solutions was processed in the plant waste system and approximately 100 Ci of long-lived fission product activity were packaged and sent to the INEL Radioactive Waste Management Complex.

12. Collection Tank Release

In December 1958 approximately 1 Ci of radioactive noble gases and iodine was released to the atmosphere from a liquid waste tank at ICPP owing to an leaking flange.

13. Liquid Release at ICPP

In December 1958 approximately 29 curies of activity (7 curies of strontium-90) was accidentally released to the ICPP disposal well from an unknown origin in the plant system.

14. ICPP Criticality

In October 1959 a criticality accident occurred in a 5,000-gallon tank when an air-sparging operation initiated an unanticipated siphoning of a uranium solution from a geometrically safe vessel into a geometrically unsafe 5,000-gallon tank containing some water. Roughly 350,000 curies of primarily short-lived gaseous fission products were released to the atmosphere via the plant stack (see Section II.C.11.c).

15. ICPP Criticality

In January 1961 a criticality occurred in the ICPP first-cycle product evaporator. A total of 5,200 Ci of primarily short-lived fission products were released to the environment.

16. Contamination of Tank Vault

In March 1962 at ICPP, high-level liquid waste siphoned from an underground waste tank into its secondary containment vault. No activity was released to the environment.

17. Tank Farm Incident

In May 1964 approximately 5 Ci of long lived fission product radioactivity were released when high-level liquid waste was accidentally discharged at ICPP during construction tie-in of new tanks.

18. Sodium Release and Fire in EBR-II Sodium Boiler Plant Building Control Room

In February 1968 approximately 80 gallons of sodium were accidentally released and immediately ignited at EBR-II. The sodium contained approximately 4 mCi of radioactive sodium-24. Approximately 0.4 μCi was subsequently released to the atmosphere.

19. TSF Waste Tank Overflow

In August 1969 a 10,000-gallon-capacity underground liquid catch tank at TSF overflowed through a vent pipe and contaminated the surrounding soil. The actual number of curies released was not determined; however, the contamination is localized to an approximate area of 8 ft^2, and current radiation levels are 5 R/hr at 1 ft.

20. ICPP Discharge Well

In September 1969 approximately 19 Ci of long-lived fission product activity were accidentally released to the ICPP discharge well.

21. ANL-W Area Drainage Ditch Contamination

In October 1969 radioactive liquid was accidentally discharged to an industrial waste drainage ditch at ANL-W. It was calculated that approximately 413 mCi were released consisting of 90% zirconium-niobium-95 and cerium-144, with traces of cobalt-60, antimony-124, and cesium-137. A survey in 1973 indicated the presence of approximately 9.4 mCi of activity remaining in the ditch.

22. ICPP Discharge Well

In December 1969 approximately 1.5 μCi of strontium-90 in excess of the discharge limits were inadvertently released to the ICPP discharge well.

23. Leak in TRA Liquid Waste Holding Tank

In July 1970 a leak occurred in a 9,000-gallon-capacity underground tank used to collect low- to intermediate-level liquid waste at TRA. Failure was due to corrosion, and the leak was detected by visual observation of a level indicator and presence of liquid in the tank sump. The liquid was transferred to another vessel, and the tank was removed to the INEL Radioactive Waste Management Complex. Approximately 0.578 Ci of radioactivity was discharged to the subsoil, consisting primarily of cerium-144, strontium-89, and strontium-90.

24. TSF Feed Tank Overflow

In February 1971 a 50,000-gallon-capacity underground liquid waste tank at TSF overflowed. Approximately 293 gallons, totaling about 0.88 Ci of long-lived fission products, were released to the surrounding soil.

25. TSF Evaporator Release

In September 1971 an accidental airborne release occurred from the TSF liquid waste evaporator. The release was determined to be approximately 266 μCi of cesium-137, 0.0142 μCi of strontium-90, and 0.0142 μCi of yttrium-90.

26. Ruthenium Release

In January 1972 approximately 1 Ci of particulate ruthenium-106 was released from the ICPP stack.

27. WCF Release

In May 1972 a leak from a decontamination line into a calcine transport air line resulted in a release to the ground of 10 Ci of long-lived fission product activity.

28. Leaking Underground Liquid Waste Lines

On April 4, 1974 approximately 20 to 30 yd^3 of contaminated soil were discovered around a corroded carbon steel vent line from a liquid waste storage tank at the ICPP. The line was abandoned, capped, and a total of 275 yd^3 of soil were removed to the INEL Radioactive Waste Management Complex (RWMC). The release totaled approximately 1,000 Ci of primarily Cs-137, Cs-134, Sr-90, and Eu-154.

On October 1, 1974 contaminated soil was discovered adjacent to an underground pipe which carried high-level liquid from the processing building to the high-level liquid waste storage tanks. The leak was caused by a 0.15.-in.-diameter hole inadvertently drilled through the pipe wall during installation of the encasement cover in 1955. Approximately 50 yd^3 of soil containing an estimated 3,000 Ci of radioactivity had been relocated to the RWMC as of the end of October 1974. An estimated 3,000 Ci of radioactivity contained in an additional 50 yd^3 of soil will be removed in the near future. This activity consists principally of Sr-Y-90, Ce-Pr-144, and Cs-137.

29. Subsurface Soil Contamination at ICPP

On September 18, 1975 an underground contaminated soil zone was discovered at the ICPP. The zone measured 150 by 20 ft along a backfilled area of a pipe trench at a depth generally between 12 and 25 ft. The source of contamination was a corroded carbon steel line in the radioactive liquid waste transfer system in the storage tank area. Approximately 14,000 gallons of radioactive liquid leaked from the corroded line. This represents an estimated 30,000 curies of radioactivity consisting primarily of Cs-137 and Sr-Y-90.

The corroded carbon steel line which was the source of the soil contamination was removed from service and capped off to prevent the possibility of future losses. The contaminated soil zone has been mapped and, if future excavation in the area becomes necessary, the excavated contaminated soil will be removed to the RWMC.

30. Diversion Valve Leak at ICPP

During a routine transfer of solution from a service waste diversion tank to an evaporator waste collection tank on January 16, 1976, solution was observed leaking from the flange on one of the diversion valves. Checks on the volume of waste received in the collection tank with that removed from the diversion tank indicate that the measurements were well below the detection limits for the diversion tank. Therefore, the amount of liquid lost cannot be determined accurately. Calculations made from field measurements and one sample analysis indicate that approximately 25 ft^3 of soil were affected, and that 500 mCi of strontium-90, 500 mCi of cesium-137, and 130 mCi of cerium-144 were released with 12 gallons of liquid. The contaminated soil remains in place under 3 to 4 ft of clean soil.

31. Break in Underground Service Waste Line at ICPP

An underground service waste line carrying condensate from an evaporator failed at the point of transition from a 3-in. to a 2-in. line, at which there is a 90° change of direction. The break was discovered on September 30, 1976. Approximately 20,000 gallons of condensate leaked to the surrounding subsoil. The condensate contaminated approximately 38,700 ft^3 of soil with 51 mCi of tritium, 2 mCi of strontium-90, 4 mCi of ruthenium-106, 2 mCi of cesium, and 1 mCi of cerium-144. The damaged section of line was excavated and repaired on October 2, 1976, and the contaminated soil covered with several feet of clean soil.

32. Pressurization of Solids Storage Cyclone at the ICPP Waste Calciner Facility

On October 26, 1976, the solids transport system at the Waste Calciner Facility (WCF) restricted, and analysis indicated that the solids storage cyclone was probably involved. During an attempt to clear the cyclone, it momentarily pressurized and blew out contaminated dolomite solids. The dolomite contaminated the roof of the vault and an area of approximately 300 ft^2 to the northeast of the waste calciner building. The release contained 230 mCi of strontium-90, 40 mCi of ruthenium-106, and 230 mCi of cesium-137. The majority of the contamination was removed from the vault rooftop and surrounding area. That remaining in the soil was covered with a layer of clean soil to fix it in place.

APPENDIX D

CALCULATIONAL METHODS

APPENDIX D

CALCULATIONAL METHODS

The calculational models and assumptions that were used in developing the radiological doses presented throughout the text of this statement are included in this appendix.

1. Whole Body Cloud Gamma Doses

The whole body cloud gamma doses were calculated by those methods described in Meteorology and Atomic Energy - 1968[D-1]. Radionuclides released from INEL facilities diffuse to large proporations, and by the time the material reaches offsite locations, the cloud (plume) can be considered infinite with respect to the distance gamma rays travel within the cloud. Based upon this consideration, it can be shown that the external whole body gamma dose to a receptor at ground level immersed in a plume of radionuclides is:

$$\text{Dose(rem)} = 0.25\ \bar{E}_\gamma \Psi \qquad \text{(D-1)}$$

where

$\bar{E}_\gamma$ = average gamma energy emitted at each disintegration (MeV/dis.)

Ψ = concentration time integral of the cloud ($Ci\text{-}sec/m^3$).

The concentration time integral was determined by multiplying the isotopic annual release by an annual atmospheric dispersion coefficient obtained by measured data at INEL. The atmospheric dispersion isopleths determined for 1974 are shown in Figure D-1. These isopleths are based on a continuous elevated release (250 ft) from the TRA-ICPP area.

The model (MESODIF) utilized to develop the isopleths is a refinement which avoids some of the previous deficiencies of the conventional wind rose technique[D-2]. The present model incorporates a boundary layer field of wind vectors in which spatial and temporal wind variabilities are included. Influences of local topography upon atmospheric dispersion are incorporated, somewhat indirectly but incorporated nonetheless, through simultaneous wind measurements at numerous locations over the Upper Snake River Plain.

The present model achieves two major improvements over the conventional wind rose technique. One improvement is the consideration of greater values of total integrated concentrations due to stagnation of airborne effluents over an area or systematic channeling and recurving of the windflow over the Upper Snake River Plain. The second major improvement results from an hour-by-hour adjustment of the rate of dilution when the hourly stability category changes.

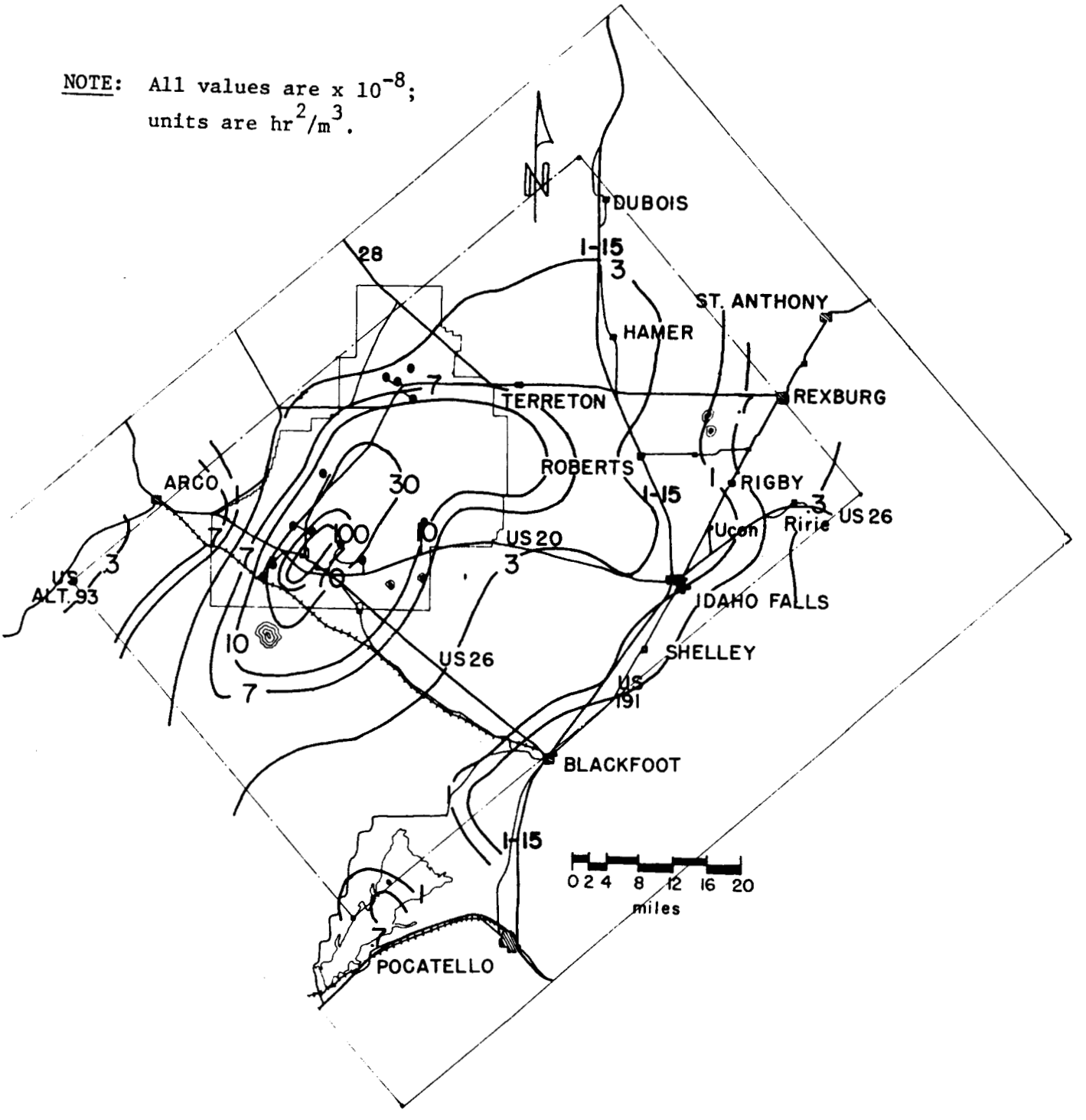

Figure D-1. Calculated Isopleths of Relative Annual Integrated Concentration for 1974.

Relative values of annual integrated concentrations for a postulated release from the TRA-ICPP complex during 1974 are shown in Figure D-1[a]. To obtain an annual time integrated air concentration (Ψ, Ci-hr/m^3), the isopleth values (Ψ/Q) should be multiplied by the annual average hourly release rate (Q, Ci/hr).

The specific isopleth values for communities surrounding the INEL were used to calculate a 50-mile-radius population dose. The high isopleth value (Figure D-1) at the immediate southwest offsite location was used to calculate the maximum offsite dose.

2. Equation for Determining Radiation Dose from Inhalation or Ingestion of Radionuclides

The equation for determining the radiological doses from inhalation or ingestion of radionuclides was determined by the following standard equation:

$$\text{Radiation Dose (rad)} = P\left(\frac{3.7 \times 10^{10}\,\text{d/s-Ci})(f)(E)(1.6 \times 10^{-6}\,\text{ergs/MeV})(1-e^{-\lambda e^{t}})}{\lambda_e(m)\ (100\ \text{ergs/g-rad})}\right) \quad \text{(D-2)}$$

where

t = period of exposure (sec)

λ_e = biological decay constant (sec^{-1})

P = uptake (Ci)

f = fraction of radionuclide reaching organ of reference

E = effective energy of radionuclide (MeV)

m = mass of organ of reference (g).

3. Method for Calculating Current and Cumulative Deposition on Soil

Figure D-1 was used to estimate the annual average air concentrations at locations on and near INEL. Using the average release rate (Q,Ci/hr), the annual time integrated air concentration (ψ,Ci-hr/m^3) was computed. The annual average air concentration (χ,Ci/m^3) was also computed for use in computing the deposition rate (D,Ci/m^2-day).

The deposition rate for worldwide fallout has been extensively studied in the United States. The following equation was developed to describe the deposition rate[D-3]:

---

[a] The concentrations were calculated assuming a release from the 250-ft-high (76-m) ICPP chimney. Plume rise was neglected in the calculations; therefore, the calculated ground level concentrations are likely to be slightly greater than what would have been measured.

$$D = (V_d + g.r)\ \chi \qquad (D-3)$$

where

D = deposition rate (Ci/m^2-day)

V_d = empirical constant for dry deposition of airborne particulates (m/day)

g = empirical constant for precipitation scavenging of airborne particulates (m/cm of rain)

r = rainfall rate (cm of rain/day)

χ = average air concentration (Ci/m^3).

The empirical values of V_d and g selected as appropriate for nuclear facility particulate releases were V_d = 200 m/day and g = 4,530 m/cm of rain[D-4]. The INEL average rainfall rate of 0.059 cm/day was used in the calculations.

The equilibrium surface contamination S_e (Ci/m^2) was computed using

$$S_e = D/\lambda_r \qquad (D-4)$$

where

λ_r is the radiological decay rate of the isotope ($days^{-1}$).

4. Method for Calculating Dose from Iodine-129 in Meat

The maximum annual average air concentration in areas open to grazing was obtained using Figure D-1 as described in Section 3 above. A release rate for iodine-129 of 0.1 Ci/yr was assumed for each of the last 20 years. The median air-to-vegetation-surface-transfer velocity was taken to be 1 cm/sec or 864 m/day for dry processes[D-5] and an upper limit value of 14,000 m/cm of rain[D-3] was assumed for wet processes. The deposition rate onto vegetation is then

$$D_v = (864 + 14{,}000\ r)\ \chi\ (Ci/m^2\text{-day}) \qquad (D-5)$$

and the equilibrium concentration on vegetation (S_v, Ci/m^2) will be

$$S_{v_e} = D_v/\chi_e$$

where χ_e is the effective removal rate ($days^{-1}$) for radioiodine on vegetation. A value of λ_e of 0.05 $days^{-1}$ was assumed.

It is estimated that the transfer parameter for ingested iodine-129 to meat is 2%/kg[D-6]. It was assumed that grazing animals consumed a maximum of 12 kg/day (dry weight) and that the forage density was 0.16 kg/m^2 (dry weight). The effective half-life of iodine-129 in meat was taken to be 33 days so, after a grazing period of 90 days, the concentration in meat would be ∿90% of the equilibrium value.

An adult is assumed to consume 80 kg of meat per year, and the dose conversion factor of 7.05×10^{-3} mrem/pCi ingested was utilized. An additional 1% of the dose per year of accumulation to account for soil-root transfer was assumed[D-6].

5. Method for Calculating External Dose from Equilibrium Deposition of Gamma Emitters in Soil

The equilibrium deposition was calculated as described in Section 3 above. The exposure rate at 1 m in air was computed using data in Table 9 of Reference D-7. The relaxation length α was assumed to be 2 cm; the soil density ρ was assumed to be 1.6 g/cm^3. A quality factor of 1 and the rad/R conversion factors from Reference D-8 were used. To determine the genetically significant dose, the multiplicative body screening and dwelling shielding factors of 0.8 and 0.4[D-4] were employed.

6. Method for Calculating Doses from Iodine-131 and Iodine-129 in Milk

Reference D-9 states that a continuous air concentration of 4.2×10^{-15} μCi/cm^3 of elemental iodine-131 gas will produce a milk concentration of 2.4 pCi/liter and a resulting dose of 15 mrem/yr to the thyroid of an infant drinking 1 liter of milk per day. Potential doses to 1-year-old children around INEL were computed using that concentration/dose relationship. No credit for decay in processing or transit was assumed; that is, the milk was assumed to be taken directly from a family cow. Dose conversion factors for iodine-129 ingestion were taken from Reference D-6. In both cases, the possible dose from milk consumption was based on the 1974 milk monitoring data.

7. Method for Calculating Doses from Ingestion of Cesium-137 in Meat

The deposition of cesium-137 from worldwide fallout has been correlated with the concentration of cesium-137 in milk and the data fit the equation:

$$C_m = 3.6\ [D(n) + 0.65\ D(n-1) + D(n-2)] \qquad \text{(D-7)}$$

where C_m is the average milk concentration in pCi/liter in year n, and D(n), D(n-1), and D(n-2) are the annual deposition rates μCi/m^2 in years n, n-1, and n-2, respectively[D-10].

It was also observed that the ability of cesium-137 in meat was consistently related to that in milk and that the following ratio held.

$$\frac{\text{(pCi/kg of meat)}}{\text{(pCi/liter of milk)}} \sim 4.^{[D-11]} \qquad \text{(D-8)}$$

The maximum equilibrium deposition rate for cesium-137 released from INEL facilities was calculated as described in Section D.3 to be 1.43 $\mu Ci/m^2$-yr; this value was used for D(n), D(n-1), and D(n-2) in the computation of the equilibrium meat concentration.

Maximum equilibrium body burdens and doses for four age groups were computed using the meat consumption rates given in Reference D-6 and the age dependent dose conversion factors developed in Reference D-4. The highest postulated dose was received by an adult. For those cases when doses were computed based on assumed consumption of meat with known cesium-137 concentrations, the same dosimetric parameters were used with the known concentration.

8. References

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